WHAT IS CLAIMED IS:

1. An image segmentation method for estimating boundaries of layers in a multi-layer body, said method comprising:

   providing image data of the multi-layer body, the image data representing a plurality of image elements;

   determining a plurality of initial interfaces corresponding to regions of the image data to segment;

   concurrently propagating the initial interfaces corresponding to the regions to segment and thereby estimating the boundaries of the layers of the multi-layer body, propagating the initial interfaces comprising using a fast marching model based on a probability function describing at least one characteristic of the image elements.

2. An image segmentation method as defined in claim 1, wherein:

   - determining each initial interface comprises defining the initial interface as a zero level of a given function; and
   - propagating each initial interface comprises moving the given function according to a speed function.

3. An image segmentation method as defined in claim 1, wherein:

   - the multi-layer body is a multi-layer blood vessel;
   - providing image data comprises using IVUS image data.

4. An image segmentation method as defined in claim 1, wherein the image elements comprise pixels and wherein the fast marching model is based on a probability density function estimating a color map of the pixels for each

region of the image data.

5. An image segmentation method as defined in claim 1, wherein the image elements comprise pixels and wherein the fast marching model is based on a gradient function estimating a color map of the pixels for each region of the image data.

6. An image segmentation method as recited in claim 3, wherein determining each initial interface comprises:

   manually tracing an initialization contour in a longitudinal plane of the IVUS image data;

   transposing reference points of the initialization contour to intersecting IVUS 2D frames of the IVUS image data;

   defining the initial interface from the transposed reference points in the IVUS 2D frames.

7. An image segmentation method as defined in claim 6, wherein defining the initial interface comprises tracing shrunk contours from an interface passing by the reference points.

8. An image segmentation method as recited in claim 6, wherein manually tracing an initialization contour comprises tracing a plurality of initialization contours.

9. An image segmentation method as recited in claim 6, wherein transposing reference points of the initialization contour comprises transposing reference points from the plurality of initialization contours.

10. An image segmentation method as recited in claim 3, wherein:
    - the image elements comprise pixels each having a color map; and
    - using a fast marching method comprises estimating a color map of pixels in each of the regions to segment in the IVUS 2D frames of the IVUS image data using a mixture of probability density functions.

11. An image segmentation method as defined in claim 10, wherein the probability density functions comprise Rayleigh probability density functions.

12. An image segmentation method as defined in claim 10, wherein the probability density functions comprise Gaussian probability density functions.

13. An image segmentation method as recited in claim 10, wherein using a mixture of probability density functions comprises determining an occurring probability value of the gray levels of the pixels.

14. An image segmentation method as recited in claim 10, wherein using a mixture of gray level probability density functions comprises iteratively finding mixture parameters via an Expectation Maximization (EM) algorithm, comprising:
    a) calculating a cost function given an observed value of said color map and a previous estimate of said mixture parameters;
    b) maximizing said cost function to analytically evaluate a new estimate of said mixture parameters;
    c) initializing said previous estimate of said mixture parameters to said new estimate of said mixture parameter if both are different;

d) repeating a) to c) until said previous estimate of said mixture parameters is the same as said new estimate of said mixture parameters.

15. An image segmentation method as recited in claim 1, wherein propagating the initial interfaces comprises constructing an arrival time function algorithm, comprising:

a) defining a speed function for the initial interfaces in terms of said probability function;

b) propagating the interface by selecting an interface point having a smallest arrival time;

c) calculating the arrival time and speed function of neighbors of the interface point;

d) repeating a) to c) until the propagating initial interfaces have all propagated across the regions to segment.

16. An image segmentation method as recited in claim 15, wherein repeating a) to c) is performed until the propagating initial interfaces are stationary.

17. An image segmentation method as recited in claim 15, wherein said neighbors comprises a number of pixels located around the interface point having the smallest arrival time.

18. An image segmentation method as recited in claim 3, wherein providing IVUS image data comprises pulling back in the multi-layer blood vessel a catheter equipped with an IVUS image data acquisition tool.

19. An image segmentation method as recited in claim 3, wherein providing

IVUS image data comprises:

a) acquiring IVUS data;

b) digitizing image data from the IVUS data on a pixel matrix;

c) storing the pixel matrix in 2D IVUS frames; and

d) calculating an estimation of mixture parameters of a probability density function forming said probability function.

20. An image segmentation method as recited in claim 3, wherein providing IVUS image data comprises:

a) acquiring in-vivo 2D IVUS frames;

b) generating segmented contours by tracing initialization contours on longitudinal planes of said IVUS image data and transposing reference points of said initialization contours on said segmented contours;

c) applying an image-formation model to said segmented contours generating simulated 2D IVUS frames.

21. An image segmentation method as recited in claim 20, wherein applying an image formation model comprises:

a) applying an acoustic impedance variations function to the segmented contours;

b) expressing said acoustic impedance variations function in polar coordinates;

c) processing said acoustic impedance variations function in polar coordinates with a polar spread function via a 2D convolution operator generating a polar radio-frequency image;

d) expressing said radio-frequency image in polar B-mode image; and

e) generating said simulated 2D IVUS frames by expressing said polar B-mode image in Cartesian coordinates.

22. An image segmentation method for estimating boundaries of layers in a multi-layer body, said method comprising:

a) providing image data of the multi-layer body, the image data representing a plurality of image elements;

b) determining a plurality of initial interfaces corresponding to regions of the image data to segment;

c) concurrently propagating the initial interfaces corresponding to the regions to segment said regions and estimate the boundaries of the layers of the multi-layer body, propagating the initial interfaces comprising using a fast marching model based on a gradient function describing at least one characteristic of the image elements.

23. An image segmentation method as defined in claim 22, wherein the image elements comprises pixels having a gray level, and wherein the fast marching model is based on a gray level gradient function of the pixels for each region of the image data.

24. An image segmentation method as recited in claim 3, wherein providing IVUS image data comprises undersampling an initial resolution of said IVUS image data in l resolution levels of IVUS 2D frames, each resolution levels being a 2^l fraction of said initial resolution of said IVUS image data.

25. An image segmentation method as recited in claim 24, wherein propagating the initial interfaces according to a fast-marching model comprises:

a) estimating probability functions in the IVUS image data for obtaining

image segmentation results of a first lowest resolution level amongst remaining l resolution levels;

b) mapping the segmentation results into a second lowest resolution level amongst remaining l resolution levels; and

c) repeating a) and repeating b) until the first lowest resolution level is said initial resolution level of said IVUS image data.

26. An image segmentation method as recited in claim 3, wherein providing IVUS image data comprises generating l scale levels of IVUS 2D frames from an initial scale of said IVUS image data, each scale level being a function of a 2^l x 2^l portion of said initial scale of said IVUS image data.

27. An image segmentation method as recited in claim 35, wherein propagating the initial interfaces according to a fast-marching model comprises:

a) estimating probability functions in the IVUS image data for obtaining image segmentation results of a first highest scale level amongst remaining l scale levels;

b) mapping the segmentation results into a second highest scale level amongst remaining l scale levels; and

c) repeating a) and repeating b) until the first highest scale level is said initial scale level of said IVUS image data.

28. An image segmentation method as recited in claim 3, wherein determining a plurality of initial interfaces comprises:

a) selecting a subset of contiguous 2D IVUS frames from said IVUS image data;

b) generating initial interfaces of an inner-layer region estimating an inner

layer of the multi-layer blood vessel;

c) searching an initial interface of a side layer of the vessel from said inner-layer region;

d) calculating a likelihood map for said side layer and growing a side-layer region from said map;

e) fitting said inner-layer region and said side-layer region on each contiguous 2D IVUS frames of said subset.

29. An image segmentation method as recited in claim 1, wherein using a mixture of gray level probability density functions comprises iteratively finding mixture parameters via a parameter estimation algorithm comprising:

a) simulating realizations of a hidden data information according to a posterior distribution;

b) calculating an estimate of said mixture parameters with a parameter estimator;

c) repeating a) and b) until convergence of said mixture parameters.

30. An image segmentation method for estimating boundaries of layers in a pulsating multi-layer blood vessel, said method comprising:

a) providing IVUS image data of the pulsating multi-layer blood vessel;

b) determining initial interfaces corresponding to the regions of the IVUS image data to segment;

c) dividing wall pulsations of said IVUS image data into a discrete number of phases with adjustable pulsation phase labels;

d) assigning the pulsation phase labels to 2D IVUS frames of the IVUS image data;

e) dividing the IVUS image data according to said phases;

f) propagating said initial interfaces according to a fast marching model by simultaneously estimating a mixture of probability density functions in the IVUS image data for each of said regions to segment and according to each of said phases.

31. A segmentation method as recited in claim 30, comprising adjusting the assigned pulsation phase labels after having propagated said initial interfaces.

32. An image segmentation method for estimating boundaries of layers in a multi-layer body, said method comprising:

a) providing image data of the multi-layer body, the image data representing a plurality of image elements;

b) determining initial interfaces corresponding to the regions of the image data to segment; and

c) propagating the initial interfaces according to a fast marching model, propagating the initial interfaces comprising, for each region to segment, (i) simultaneously computing a speed function for the propagation of the initial interfaces based on a probability function describing at least one characteristic of the image elements, and (ii) mapping a time function of the propagating initial interfaces.

33. A data acquisition system for segmenting images by estimating boundaries of layers in a multi-layer body, comprising:

a) a catheter including a transducer for providing image data, the image data representing a plurality or image elements;

b) a data acquisition tool including:

i. a digitizer in communication with the transducer for digitizing the

image data;

ii. a memory for receiving and storing the digitized image data;

iii. a calculator for estimating, for each of the layers, probability functions describing at least one characteristic of the image elements;

iv. a processor in communication with the memory and the calculator for simultaneously estimating the boundaries of the layers of the digitized image data by using a fast marching model based on the estimated probability functions.

34. An image segmentation method as defined in claim 1, wherein the image data comprises B-mode IVUS image.

35. An image segmentation method as defined in claim 1, wherein the image data comprises RF IVUS image.

36. An image segmentation method as defined in claim 1, wherein the fast marching model is based on a probability function estimating the gray level distribution of pixels of the image data.